"I have found so much fun, with all these groups of internet people"

Peter Kirstein ARPANET international pioneer.

Early in the development of the Internet, he co-authored (with Vint Cerf) one of the most significant early technical papers on the internet concept. His research group at UCL played a significant role in the very earliest experimental Internet work. He became Professor of Computer Communications Systems at UCL in 1970, and brought the first ARPANET node to Europe in 1973.

Interviewed Oct 31st, 2006 at the Kelvedon Hatch secret nuclear bunker (UK)

I was born in Berlin, Germany in June 20th, 1933. However, I left Germany when I was three and a half~~3~~ years old. Fo~~ai~~r~~ly~~ obvious reasons, having~~if you~~ left at that age~~'re at 3 and half years to 33~~, ~~so~~ I wouldn't consider myself German, I would consider myself British. About my studies, I went to Cambridge, England from 1951 to 1954 but the British system was that you took your scholarship exams to University and then I had nine months or a year and nine months to spare. M~~, m~~any people went to the ARMY then (we still had conscription), but I actually went to California and spent 9 months in UCLA. T~~, t~~hen I came back to do~~finish~~ a degree in~~my~~ mathematics and engineering at Cambridge. During this period~~Later on~~ I had a couple (1951 and~~-~~ 1952) of summer jobs with the ARMY engineers in~~at~~ Los Angeles. So I had a UK-US background already then.~~, and t~~hen I went back to the US and got my PhD in Electrical Engineering from Stanford in 1957. Then I went back to Europe initially for 1 year. A ~~(but a~~s I wanted to go skiing~~,)~~ I joined~~went to~~ CERN in Geneva. I~~,~~ stayed there for~~during~~ 4 years, including six months in Russia at Dubna. Then I joined ~~working for~~ the US General Electric, working in Zurich for four years. ~~and then~~ I went back to Britain in 1967 to the University of London Institute of Computer Science, transferring to University College London six years later. I have been a Professor there ever since.

Throughout my life ~~So up to then~~ I have ~~had~~ had a lot of transatlantic experience. W~~ and w~~hen I left General Electric, I wasn't actually replaced for the next 25 years, so I stayed as an external consultant for GE. All this protracted ~~So I kept having this~~ European-US background is very~~; I think~~ it's relevant to ~~the whole of~~ my internet activities.

He is a Fellow of the Royal Academy of Engineering, and a Foreign Associate both of the American Academy of Arts and Science and of the US National Academy of Engineering. He was awarded the ACM

SIGCOMM Award and the IEEE Senior Award in 1999. He became a Commander of the British Empire (CBE), and received ~~and~~ the Internet Society's Postel Award in 2003.

~~The problem with the NPL activity was that even it's quite true they had the first switch, it was one switch in NPL; it never went through any distance at all; it was never even outside the NPL.~~

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Do you remember when you had your first contact with a computer?

No, I don't quite know exactly when, ~~I do,~~ but ~~I don't remember~~ if ~~that~~ was ~~a computer.~~ i~~I~~n 1951 when I first went to UCLA. There~~,~~ I saw a one hundred meter long mechanical differential analyzer and ~~I~~ also ~~saw the~~ **SWAC**, the South West Automatic Computer, I only saw ~~it~~ that one at a distance. There were two computers built at roughly the same time, SWAC and the **SEAC** the South Eastern Automatic Computer.

So that's what I saw as my first one. Later, after two years mathematics study at Cambridge U, I considered working with ~~and when I got back to England, I also saw the~~ **EDSAC**~~, which was a Cambridge computer~~ at their Mathematics Lab. That was one of the most~~a~~ powerful, real computers at that time, T~~t~~hen I went to Stanford U. There~~and that was~~ the first computer I used, ~~I think it~~which had~~was~~ 19 words of storage, was the IBM 605~~;~~. ~~And~~ that was the most powerful computer at Stanford in 1954, and~~, so that~~ was the first one I used in my microwave research.

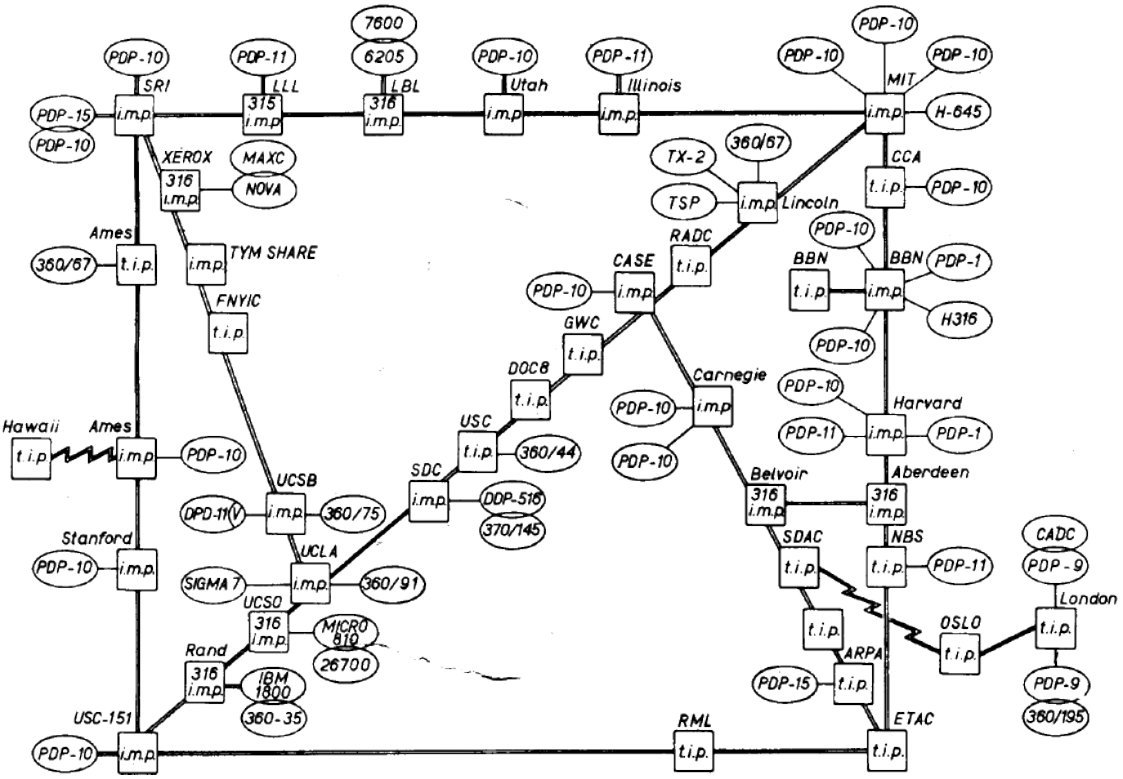
What was your first contact/experience with the ARPANET?

Sorry to be long in answering these things but I don't quite know how to describe my first contact. In 1965 or 66, I was visiting UCLA and met ~~first of all there was~~ a graduate student sitting up on the roof there ~~-~~, somebody called **Vint Cerf**. There ~~was an open space on the roof there, it was a flat roof and~~ Professor **Jerry Estrin** described to me the network they were building. ~~And the network~~ A~~a~~t that stage, UCLA had three IBM 360/91s~~;~~ one was at the Electrical Engineering Department, an~~the~~ other at the Western Data Processing Center and the last one was at the medical school. Those three were going to be connected together with three~~an~~ IBM 360/~~-~~40s as front-ends, ~~in~~

~~Princeton~~ and that was going to be a network experiment. This~~And that~~ was actually the first network I had seen and it ~~probably~~ sparked off the idea of the ARPANET a~~(~~ few years later~~)~~, ~~from some sense,~~ because it wa~~i~~s ~~for~~ the first time someone had ~~you~~ put a front~~-~~-end machine behind a host.

Around this time I also saw, and discussed with Donald Davies, the first packet-switched network he was building at the National Physical Laboratory (NPL). I chaired a session on the NPL network at IFIP in early 1968 – before the ARPANET was operational. I discuss this network more later in this interview.

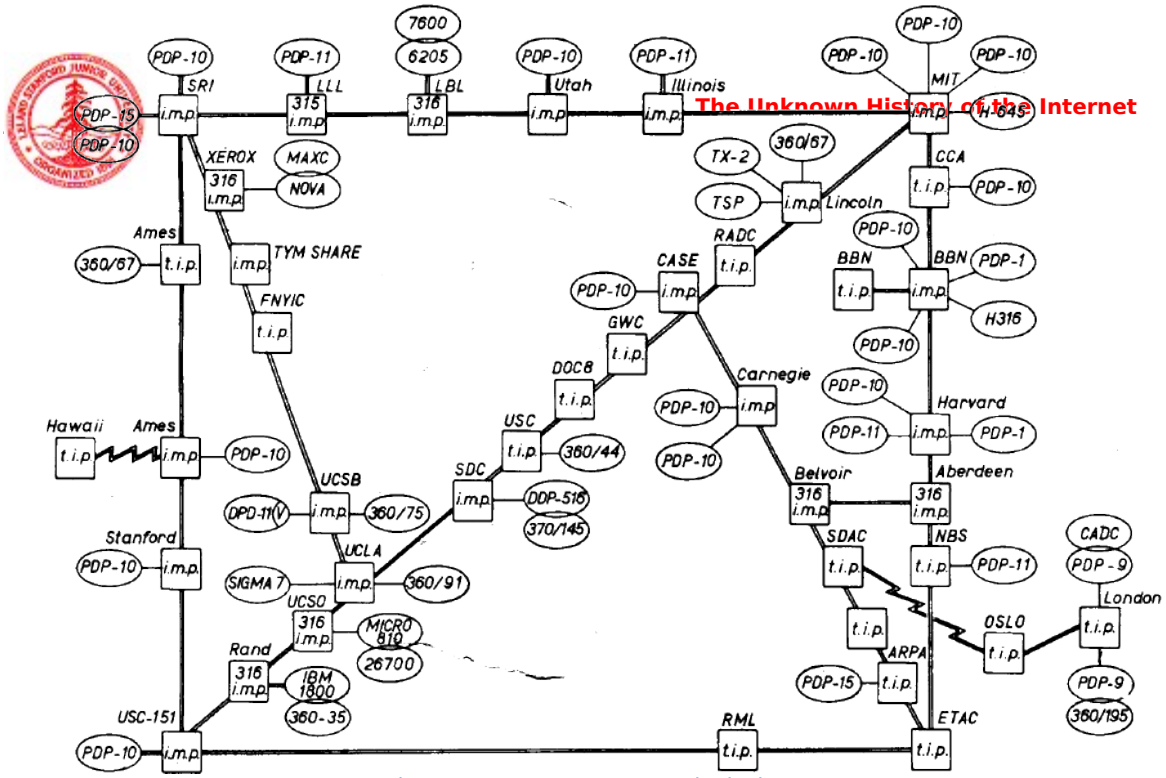
Later on I ~~was~~ followed~~ing~~ the ARPAMET ~~is~~ developments closely, partly as there was early discussion of my obtaining an international



node. In the ~~as within~~ early 1970~~'~~s I used to go every year to UCLA so I certainly ~~suddenly~~ saw the beginning of the ARPANET, I kept bothering a gentleman by the name of **Bob Kahn** (at the time working for BBN) ~~and kept~~ asking him about modems and how you connect things and so on. He ~~couldn't~~ didn't actually believe anything would happen out of it, and~~I~~ was very surprised when at the end it turned out that it did.~~yes,~~ H~~h~~e had by that time left BBN and gone to DARPA. Bob Kahn was ~~actually~~ the systems designer of much of the ARPANET system. The actual building of the IMP was of course by **Dave Walden** and **Frank Heart** and various other people~~;,~~ ~~and from there~~ you can find the rest from all the histories in this book, so I don't need to tell you the ~~hi~~story.

September 1973. ARPA NETWORK logical map.

~~But actually~~A ~~a~~lready, in October 1972, when there was that famous ARPANET demonstration~~/~~ conference in Washington DC, I was giving talk~~sing~~ about the European Network situation. The European activity w~~so it h~~as ~~been~~ deliberately ~~then,~~ compl~~e~~imentary to what was going on in the US~~tates., and~~ Hence~~that when~~ I suggested to **Larry Roberts** (the ARPANET Project Officer~~architect~~) that we in London would do something different from anybody else in the world~~;,~~ we would connect computers remotely to the ARPA TIP, which wasn't happening in the ARPANET community. B~~b~~ecause all I had was a small computer~~s~~ (Digital PDP-9), ~~and~~ I was going to connect to the CDC 7600~~ATLAS~~ computer in the University of London C~~c~~omputing C~~c~~enter (ULCC) and~~:~~ the IBM 360/195~~40~~ at the Rutherford and Appleton Laboratory (RAL)~~that stage~~, which was some 70 miles away. I~~,~~ ~~and I~~ was going to connect them: looking one way exactly like an ARPANET computers, with all the right protocols, and the other way exactly like ~~an IBM front end,~~ an IBM ~~terminal~~ or CDC terminal. This ~~, that~~ was a new concept~~to them~~ at the time. ~~I and i~~f you look at the early maps somewhere around October or November 1973, you will see the ARPANET terminates at UCL on my PDP-9 but the hosts are called the RAL IBM 360/195 and ULCC 7600~~ATLAS computer center~~. Later we added also the C~~c~~omputer A~~a~~ided D~~d~~esign C~~c~~enter – this was a Depart of Trade and Industry Centre in Cambridge. Thus~~So~~ all those three were remote from me, but from the US si~~d~~te, they looked ~~alike~~ as if they were ordinary ARPANET hosts. ~~We used the IBM terminal protocols and in fact as early as October 1973, we've done it already; I gave a talk saying that they rather find that machine on the ARPANET.~~



September 1973. ARPA NETWORK logical map.

For the early RAL linkage we used the IBM HASP terminal protocols. In early October 1973 this link was already operational, and I gave a talk stating that this machine was on the ARPANET. After the talk, one of the RAL systems staff ~~Somebody~~ came up to me ~~from their system staff afterwards~~ and said "that was a very good talk you gave, however of course, it wasn't true. ~~W~~, ~~because w~~e can ~~not~~ tell because we have never seen any sign of being on the ARPANET". I responded~~said~~ "~~T~~that's exactly right, all you see is something that looks like an IBM HASP terminal, which is attached to you, but on the other side~~way around~~, it has got the whole ARPANET around it". They were rather worried about that – but t~~. T~~hat had been ~~was~~ part of my original proposal in 1971.

I had early financial and political problems getting the project started. ~~While t took about two years to get the whole thing agreed,~~ I was trying to get some funding from our Research Council, which I never really got, the whole activity ~~and it~~ was nearly ruined. ~~at the beginning because~~ **Larry Roberts, then the DARPA Office Director,** ~~-~~offered me an ARPANET Terminal IMP (TIP[1]~~s~~) and I put that into a proposal to the British Science Research Council (SRC). T~~, t~~hey didn't believe the offer,~~me~~ and the C~~c~~hairman of the SRC~~cience Research Council~~ wrote to the D~~d~~irector of DARPA (Steve Lukasik), requesting confirmation; ~~the director of DARPA~~Steve had~~s~~ heard nothing about this at all and so he asked Larry Roberts what was all this about, Larry ~~didn't like it and got~~was very upset that Steve had heard from the UK~~because~~ before he had been briefed locally on

[1] TIP: *Terminal Interface Processor*. The first one was deployed in Sept. 1971, enabling individual computer terminals to dial directly into the ARPANET thereby greatly increasing the ease of network connections (compared to their bigger brothers the IMPs) and leading to significant growth. Later they were called *gateways* and nowadays we call them *routers*.

something as unorthodox ~~the director of DARPA, "he was going to do something as surprising~~ as "exporting the ARPA network to Europe"...

Later I got to know **Steve Lukasik** quite well, ~~who was (from 1970 to 1975) the Director of the whole DARPA~~ and he approved of the idea. Since I was writing the proposal to a small department, pretty far down the hierarchy, ~~but~~ it was surprisingly that it was considered ~~enough~~ important enough to go ~~that it went~~ all the way up to the Chairman of the SRC and the D~~d~~irector of DARPA. ~~(the equivalent to the National Science Foundation) who then wrote to the director of ARPA for confirmations. At this stage~~ I was also trying to get 20 or 30 thousand pounds funding~~approval~~ from the Department of T~~t~~rade and I~~I~~ndustry, ~~. and~~ so I wrote to a colleague at the largest British computer company (ICL) for political support – not financial backing ~~.. who I knew very well and~~After ~~-~~waiting ~~reply~~ for 8 months, ICL ~~and when they~~ finally replied that~~,~~ they ~~said they were~~had look~~ed~~ing at the proposal~~it~~ very carefully, and concluded ~~. I was only asking for 20 or 30 thousand pounds I think and they decided~~ that it was much worthwhile to spend two weeks on a visit to the ARPANET in the US than to do it ourselves!~~.~~

I am not sure if this is answering your *first contact* with the ARPANET question.

~~So,~~W~~-~~hile I didn't get funding~~approved~~ from either ministry, ~~at all,~~ there were no objections from Steve Lukasik. Therefore ~~and~~ I got 5.000 UK pounds from **Donald Davies** (from the British National Physics Laboratory) and the offer of a 9.6Kbps link to NORSAR near Oslo, where the then extant transatlantic link to DARPA in Washington ended. The funding from Donald ~~at~~ was the most that he~~Donald Davies~~ was allowed to authorise~~d~~ from his own funds. B~~ and it arrived so I could get started but then my computer arrived b~~etween 1971 (when the whole thing had started to be negotiated) and 1973 when the computer arrived, ~~the TIP was duly shipped in July 1973, its value was somewhere around 50.000 US dollars and that was the value declared but between 1971 and 1973~~ the British ha~~d~~ve introduced ~~something called~~a ~~value~~ Value A~~a~~dded Tax (VAT) ~~and~~ that was 10 percent ~~roughly~~ of the value of any goods. So, when this TIP arrived, I received~~'ve got~~ a bill at the same time for 5.000 UK pounds in order to import the TIP ~~- which, well that~~ was my ~~tutelage~~ total funding!~~money.~~ So ~~what I did~~ I stated that ~~was~~ I would pay under protest, but ~~said I~~ would appeal the ruling. I ~~-~~n~~but on~~ the mean time the equipment should be released~~I should have it~~. After ~~So I appealed and I appealed for~~ about a year and half, my appeal ~~and that~~ was ~~then~~ turned down by the T~~t~~reasury, who stated ~~and I was told~~ that it was a political issue, and I couldn't do anything about it. So I then wrote to the T~~t~~reasury stating:~~and said~~ "A~~a~~lright, I will~~ould~~ export this TIP, but since it belongs to the US Mnistry of Defence, " ~~and then~~ I will~~ould~~ re~~-~~import it under the Exchange of Forces Agreement Act

between ~~apact from~~ the US and~~to~~ UK". They didn't like the sound of this. B~~, b~~y this time (in 1975) I already had contracts from 6 ministries. I was then called in to a very high level officer of the T~~t~~reasury who interrogated me saying: ~~and said~~ "W~~w~~hat you're doing is of no interest to the D~~d~~epartment of H~~h~~ealth?" "No sir", I replied although I was running a link to the US National Library of Medicine. ~~had a contract from them"~~ "It is of no interest to the British Library?" "No", I replied although I had a contract from them~~".~~ "No interest to the D~~ d~~epartment of E~~e~~ducation and S~~s~~cience?" "No", although I was running a service for all British universities accessing the ARPANET. They continued in the same vein with ~~and they went on to~~ the M~~m~~inistry of D~~d~~efense, Trade and Industry and Atomic Energy Authority – with all of whom I had contracts to provide ARPANET services. ~~and so on", T~~ ~~t~~hen the Treasury~~y~~ wrote me an official letter stating:~~said~~:

> ~~The treasury department to Peter Kirstein: "well, in that case, we hereby give you permission,"~~ S~~s~~ince your activity~~it~~ is of no interest to any ~~of~~ British ministries and only to the United States Department of Defence, you have permission to import this and any subsequent equipment for this project free of tax and duties".

For the next 10 years, based on this letter, my~~this~~ small research group ran ~~was on the end of that time running~~ a complete international service. Whenever anyone questioned this, and wanted to run it themselves, I readily agreed – but pointed out that they would need to pay the taxes and duty on the ~~with~~ computers which were, by that time, ~~–~~in different locations including the Ministry of Defense~~.~~, British Post Office, and different university sites.

Shortly a~~A~~fter ~~a year we started with~~ my ARPANET link became operational, **Bob Kahn** at DARPA started a ~~we heard about this~~ new satellite project ~~network~~ called SATNET. The project could not go live ~~,~~ ~~so I had some more computers for SATNET we put them on the defense research laboratories so they had more equipments. Bob Kahn actually started SATNET more or less in 1973 to give a contract to BBN but it couldn't happen~~ until arrangements had been agreed with COMSAT, INTELSAT, the British Post Office station at ~~first of all the~~ Goonhilly Downs[2] and the Tanum earth station in Sweden, which ran the transatlantic link to Norway. To extend the project, he was discussing also ~~in UK and Tanum in Norway had been taking care of~~

[2] Vint Cerf wrote when asked on this topic: Before UCL was put up on the ARPANET, only the NORSAR (Norway) facility was connected by satellite. Bob Kahn worked out an arrangement to increase the total capacity of the system and also arranged for UCL to be connected to the ARPANET. Initially NORSAR was connected to the ARPANET by a dedicated satellite connection. The capacity was increased and UCL was connected to NORSAR by land line, thanks to the generous offer of the British Post Office. The satellite ground station was at Tanum, Sweden. Later, the Packet Satellite system was fielded via INTELSAT IVA and UCL was connected to the SATNET and the land line to NORSAR was removed. UCL was connected to the SATNET through a ground station at Goonhilly Downs, (UK). NORSAR/NDRE was re-connected to the ARPANET by way of SATNET which also used a ground station at TANUM (SE).

~~properly and then it had to involve some offices, so he was discussing~~ with three other countries[3], Germany, Italy and Canada.

By 1973~~About that time, first of all~~, the British had already nation-wide access to ~~a centralized research network based on~~ its large RAL IBM-360/195 ~~(by that time 360/95 or 361/95) and they had a~~ via a centralized IBM network.

At the same time there were two other centralized networks~~:,~~ one was based on a ULCC CDC 7600 in London and the other on the ~~was~~ ATLAS at the Computer Design Center in Cambridge. Because they all already connected in remote coputers, albeit with proprietary protocols, they were suitable for ~~I~~ connecting to ARPANET. In practice,~~ed all them together;~~ the CDC one didn't work very well because they had the wrong sort of protocols, we couldn't do anything very interactive. T~~ but t~~he others were all on for quite a while and in the meantime the networks around them grew and I had to change and convert what we were doing to make it still stay transparent to the US.

On **July 25th, 1973**, the University College London node of the ARPANET passed its first data packets between London and the Information Sciences Institute in California, USA. This is believed to be the first instance of an international heterogeneous computer network;

Of course, we had many other problems, for example that involving our Domain Name. ~~earlier and that was when **Jon Postel** was very annoyed with me because the British department of trade in the late 1920's started talking about car registration and they decided that the British country code was **.GB**.~~

The UK, via UCL, were the third ~~When I said we were the first~~ domain name to be adopted (after .EDU and ~~.outside the~~ US). In 1983 ~~and I had to~~ choose ~~nothing better and chose.~~ UK because that covered Great~~was~~ Britain and Northern Ireland~~, so I just chose .UK~~. Around 1986 Jon Postel was trying to put some order into domains~~things~~ and wanted to have the top-level country names aligned with the list published by the International Standards Oganisation. Unfortunately the British Department of Trade in the late 1920s started talking

[3] Germany and Italy were no particular problem; they happened but they never did anything because they never had the infrastructure and there were too many problems with what they were allowed to do. Norway never went very far for the same sort of reasons and Canada never got started for a very interesting different reason. In Canada, it was Bell Northeron who was interested; it was ~~but Bell Norton was r~~esponsible for all communications meetings with the USA. All Canadian The satellite communication was the province of OTC. OTC was unwilling to give up ~~were under, whatever it was, the agency part of UQC or something like that and they were not going to give up t~~heir exclusive rights to international satellite communication, but Nothrern Telecom were unwilling to compromise their exclusive ~~they had no r~~ights to connect to USA. S ~~and therefore s~~ince those two couldn't agree, Canada could never join. B~~ut C~~omsat was a partner; through them , ~~so w~~e had t~~hem and a~~lso some smaller stations connected in~~at the time.~~

about car registration and they decided (incorrectly!) that the British country code should be **.GB**. Thus Jon said to mesaid: "*Peter, you've got to choose, you can't have two and .GB is the proper*[4] *one, so you've got to choose whether you would use .GB or .UK*". There was a 4 or 5 years period in which we were discussing this backwards and forwards. T, the British authorities rejected on principle being dictated to by the Americans on this, ; you can imagine all the rest. Even in 1988, it was estimated that it would cost 25 million pounds to change to .GB, and nobody was prepared to foot the bill. Al at one stage I guaranteed to Jon Postel that within one week of his moving all of the United States onto the .US top- -level domain, I would move all of Britain onto .UK, b. But he didn't think this was very funny, perhaps that should be one of my anecdotes. ThereIt was an even worse suggestion; one the Briton ish, one of them even wanted to have **.UKUS** whenever to show that one was using the ARPA/, the internet protocols and then **.GB** whenfor the one that usinged the OSI protocols. That was one of the proposals, but I refused that proposal, saying one; I said that was just not the way things are supposed to be done. In fact .GB still exists, but I do not think it is used. I am not sure if the MoD[5] has stopped using it.

The ARPANET grew steadily in the early 70s, and Cerf and Kahn proposed their revolutionary Internet Protocol in 1974. By the time that daily traffic on the ARPANET exceeded 3 million packets, in 1975, Bob Kahn from DARPA decided to fund three contracts: one at Stanford, California (with **Vint Cerf** and his students), another at BBN, Cambridge (with **Ray Tomlinson** and **Bob Thomas**) and the third to us at UCL to develop and implement what at the time was called the Kahn-Cerf TCP protocol. The Stanford team produced the detailed specification and within about a year we had three independent implementations of TCP that could interoperate.

The other thing whereBecause of our early experience with TCP/IP – and with the corresponding OSI protocols adopted by the British networks, the UCL gateway was we werethe first is to use the internet Pprotocols exclusively for service[6].;

[4] As for 2010 only one sub- domain is still registered in **.GB** (ISO 3166-1 official code for the United Kingdom) and no new registrations are being accepted for it. Sites in the UK use **.UK** as their country code Top Level Domain.

[5] MoD: stands for the Ministry of Defense.

[6] As my PDP-9s (which I bought in 1968) was getting rather long in the tooth bylonger tubes in 197669 and I had to get rid of them; there wa's no point in putting in the ARPANET NCP[7] again so I started putting in the internet protocols (TCP/IP) and started running services with them. After all, 12 years wasit is probably is a long time for a communication computer with at most 32Kthousand words which hads to do all these work of translatings about changing protocols, changing domains etc. Anyway, so we wenttried to go into service somewhere around 1981, well before the main switchover . Wand we complainedt because it was just not ready for service even though but we had to run an inter national service on it. It was only when our US colleagues and is within when they were started running on their services after the switchover day in January 1983, that our , the US colleagues started to understand why we had beenwere complaining.

Daily traffic on the ARPANET exceeds 3 million packets and DARPA funds three contracts: one at Stanford, California (with **Vint Cerf** and his students), another at BBN, Boston (with **Ray Tomlinson** and **Bob Thomas**) and the other to us at UCL to develop and implement what at the time was called the Kahn-Cerf TCP protocol. The Stanford team produced the detailed specification and within about a year we had three independent implementations of TCP that could interoperate.

So UK was the first domain name; I knew nothing about GB until 3 or 4 years later. It may still exist, I am not sure if the MoD[7] decided to use it.

One of the principal mechanisms to keep whole secrets to put the whole projectthing working was that I set up a Political Governing Committee (GC) with representation from all organizations providingon the budget. Originally this included , which was formed by someone from the British Ppost Ooffice (part of which later became British Ttelecomm), ; it had somebody from the academic side, and originally NPL representing the Department of Industry (DoI)different people, different times. InAround about 1974 I wrote to the Mministry of Ddefense (MoD) because theis whole project was in danger of thing might have been collapseing. T and they sent the chief of guided missile to talk to me and they decided to give me a contract also. V and various people for instance **John Taylor** was the first person on my GCgoverning committee from MoDthe ministry of defense; he later became the Ddirector of the Rresearch Ccouncils. TAnd there was always somebody from MoD on the CC; defense and John Laws, the MoD GC member they took a guess around about 19854/65 when theis first question of .GB came upout, that it the GB would be the one that would wins the battle, not UK. Hence , so he moved some of the MODministry defense people on to GB but he couldn't move themit back. so he got frozen for a while.

Making things compatible on both sides_:

First of all,T the whole principle of my service hingedwas based on whethern one could or couldn't manage these major differences between the two sidtes. F, so for instance, file transfer in the ARPANET was interactive; in the British system, (so called colored books), it was a batch link; how do you give reasonable responses when you are trying to go between such things? We were very deeply involved in all the British systems, which all were based on what the telecom companies were doing at the time.

The standards were described ast the so called *Colored Books*; we obviously participated in the formulation of those, particularly in the Grey book (about the email). It was a European project, yes, and a

[7] MoD: stands for the Ministry of Defense.

British one. The British really pushed the *Colored Books* themselves. To keep our connection and system working we had to be completely ~~c~~*Colored* ~~b~~*Book* compliant in~~at~~ one direction~~way~~ and then completely ARPANET-compliant the other way. So what one~~you~~ could ~~do~~ and ~~you~~ couldn't do on that was already important.

~~The other think is~~W~~ w~~e were heavily involved in SATNET and some of the packet voice activities at the time. I believe we were the first to send facsimile over the ARPANET/ W~~ and w~~e also~~, actually~~ we did some measurement because around about 1977 the British started putting in their own packet~~-~~-switched service[8].

We were part of the SATNET experiments, but then somewhere around 1979, SATNET stopped being an experiment and the Germans, Norwegians and Italians, stopped participating. However; we ran SATNET as a service for the next six years. A~~ and what we a~~ctually ~~did was we ran SATNET for~~ some of our traffic ran over SATNET and some over~~for~~ the International Packet Switch Service (IPSS). IPSS was based on X.25 protocols. We did some measurements on that for British Telecomm~~. and we also had traffic going one way or the other.~~

In your opinion, what are the key characteristics of Internet?

Well, I think one of the most important one is that you have a particular level at which interconnections are possible and that you can isolate things both above and below that particular level. That means you can have different network technologies below that level and different application technologies above that level. The fact that it is a universal level with a well-known interface~~value~~, gives~~ave~~ one a lot of freedom in what applications one connects with and how one connects with~~.~~ Different network topologies.

The problem is the protocol isn't completely optimal, so as long as I remember, there ha~~s~~ves been attempts to break through the rigid levels and optimize things below or above. O~~ and o~~f course if one does, one is going to break this universality, but it will become more efficient.~~,~~ W~~and w~~e've had this dichotomy for as long as I remember; it is still there.

People are putting QoS (Quality of Service), signalling what you need for security~~QoS~~, etc. That's always been~~;~~ the key problem is that you had the capability of having the i~~n~~sou~~u~~lation and then you fiddle~~ll~~ either above or below with various mechanism for guaranteeing quality of service or security or anything else. This is not a show-stopper~~It is not a deadlock~~, I~~ mean i~~t works fairly well, it works better

[8] First of all in 1977 it was called **EPSS**: Experimental Packet Switch Service then called **PSS** Packet Switch Service and later on changed to **IPSS** International Packet Switch Service.

now than it used to~~; the reason that it works better than it used to is~~ because we can now over-~~-~~engineer on bandwidth. It is interesting actually; one of my main projects now is concerned in introducing the internet satellite based in n~~f~~ew developing countries. We have limited bandwidth; 30 Mbps for the whole two~~2~~ regions of the Caucasus and Central Asia. Nevertheless, ~~; but~~ we want Voice over IP and videoconference; one can do that by putting in the right Quality of Service (QoS) in the routers. W~~, w~~e def~~have ti~~n~~m~~e terminals, which should get priority and then those ~~get priority and~~ go faster. We are technically able to do that. But on the other hand, that's very heavy work on the routers; so what I have ended up doing is over-provision~~design~~ing the bandwidth, to increase the quality, lowering the routers' work.

I am a great believer in IPv~~V~~6, which ~~of course is touching it and by the way~~ I think ~~that~~ will ~~end up~~ certainly happen – even though current acceptance is very slow~~ing~~. The main reason that it will make it happen is because so many of the newer protocols are being aligned for the IPv6~~v6~~, ~~-~~so sooner or later it will have to happen.

The other characteristic is the big scalability of IPv4; ~~I mean~~ the fact it survived at all from the original experiments in 1975 to what happened to it in 2006, is really incredible. We always thought about doing a few~~one or two~~ conversations over this thing but to actually have the level of real-~~-~~time traffic we now have, ~~it~~ was never imagined at all.

Then of course the next is the various application-~~-~~specific protocols, in particular of course, the web. ~~I found it easy to adjust to the things that existed underneath,~~O~~o~~ne thing which still needs working through is the fact that there are a number of different ways of doing security and that causes real problems – that ~~...~~

~~And~~ I don't see any sign of that being resolved. There are too many vested interests. VPNs mean~~s~~ that you have one form of control by one set of organization~~s.~~; Y~~y~~ou can try to mandate IPSEC but you're not going to have that done on the mobile side because the mobile operators~~y~~ want to have security based on the SIM cards that~~what~~ they control. ~~; you have today from HP, where you could have some cards in the laptops, that's the security which the mobile telephone world would like better and~~ T~~t~~he fact that you have so many different types is very unfortunate and yet inevitable~~they are all essentials. Sorry, it's essential to have it somehow~~.

What do you consider the most important milestones in the development of the network?

- 1974 I think the first really important milestone was the concept by Bob Kahn, of having completely different networks, at some level in protocol, to work together. Analyzing gateways that could work and we finally realized that in 1978.

  Vint and I wrote (the only joint paper we have ever written together) specifically analyzing gateways and different types of issues which could exist. He was my project officer[9] in DARPA at~~nd~~ that time. We had contracts for some 30 years, and ~~I know that we~~ gave reasonable value for the small contracts we had with them. ~~So I think~~C ~~c~~learly, the concept of connecting networks was the first really important one.

- 1983 The next really important one was actually putting network connection into large-scale ~~them to~~ practice. T~~ and t~~hat came in several ways; on the one side, the introduction of TCP/IP altogether and second of all, the growth in access networks, separate from the backbone networks, but still usinge~~d~~ similar protocol structures, very easily connected.

- 1984 Clearly the DNS, which was not part of~~f~~ the original TCP/IP concept was a huge advance.

- 1991 And then of course, the next biggest milestone was the winning of the protocol wars (TCP vs. the "official" OSI from ISO), which was an absolute and complete victory.

- 1992 The fact that the simple World Wide Web concept met so many of our needs, and could use a single underlying network ensured the phenomenal growth and universal take-up of the Internet that we have now seen.

- The milestone that I am still waiting for is when there's a real acceptance in the US that IPv6 is a good idea. So far, all of the manufacturers are providing it but there is a very big sign of data. The real people pushing for it are the Chinese and the Japanese. In fact the main reason for Cisco went into it was because of a NTT request for tender, which requested that IPv6P~~v6~~ be available and Cisco couldn't respond; ~~and~~ Cisco doesn't like not being able to respond to a large tender request!. S~~s~~o immediately they put in an IPv~~v~~6 program and coordinated a large~~virtually after the~~

[9] You see I have always had on the one side these people I mentioned in UK, then a distinguished set of project officers from DARPA because I had DARPA contracts from 1973 to 2003. The list of people who were my project officers is a very distinguishedc~~t~~ list; It was originally Larry Roberts, later it was Bob Kahn, thenit ~~was~~ Vint Cerf, Steve Crocker, t~~hen it was~~ Paul Mockapetris, Mike St Johns ~~then it was Nicson John, Dyke Moon,~~ Hillary Orman, Doug Maughan - all the people you know of one way or the other; they all have been my project officers and we were always t~~rying to p~~utting a slightly different flavor on things.

European project (6NET). Nowpushed, all the American companies have implemented IPvv6 on their products. By thatut I mean it's completely standard on Microsoft products, it's completely standard on your stack on Cisco and Juniper routers. , no difficulty at all. It's a chicken and egg situation;, there's no immediate shortage of address space in the United States. When the US runs short out of addresses this will be a major boost to deployment. Asered and soon as the US cross over to deploy IPv6, other countries will cross over too. It is because and there's much greater address shortage in Japan and China that they have embraced it first..

Why were we connected through Norway to the US-ARPANET?

The reason for this is that there was in 1971 a Nuclear Monitoring Research Office (NMRO) in DARPA. That was doing seismic monitoring and operated three large seismi arrays in Alaska, Montana and Kjeller (Norway). The data went via 2.4 Kbps data links to the Seismic Data Analysis Centre (SDAC) in Washington. For this reason there was a 2.4 Kbps satellite link from Washington to the British ground station at Goonhilly, and thence by landline to Kjeller.

Larry Roberts' initial idea was first to put the NORSAR array onto the ARPANET to ease the data transmission, and then to increase the line speed to 9.6 Kbps, interrupt the link in London, and put us onto the ARPANET. He thought that this process would be straightforward, and would not need much funding. For the first stage, It was fairly easy just to put in an extra IMP; he was already deploying 40 or 50, so putting one more in Norway would not be very difficult. They could see already then, that they are going to need to expand their monitoring network.

For the second stage, Larry did not understand the problem! He thought he could just interrupt the line in London, re-terminating at UCL, add an IMP, and then go on to NORSAR at nominal extra charge. He did not then realize the international tariff problems. In fact the expenditure would have been very significant for the extra link. He was not prepared to pay this extra international communications cost, but I persuaded the British Post Office to donate it to me for a year.

In fact the Nordic Satellite Earth Station came on stream in 1972, and there were various other changes in the following years. Thus the timeline is given below.

1970: US starteds receiving seismic data from the NORSAR array at Kjeller (Norway) at 2.4 Kbps via satellite link to Goonhilly and then land-line to Kjeller.

Seismic data went by cable from Norway to UK and then by satellite to US. Measuring nuclear testing was the initial reason to have that expensive international connection established.

1972: NORSAR Seismic data goes to US directly through Tanum (Sweden) by Satellite and thence land-line to Kjeller.

1973: NORSAR link upgraded to 9.6Kbps. ARPANET connected to Kjeller Computer Centre. UCL connected by 9.6 Kbps terrestrial link to Kjeller.s by satellite to UCL Link established UCL to RAL,Royal Radar Norway & U .Hawaii.

1974 Links established to Computer Aided Design Centre (Cambridge), Fusion Research Centre (Culham) and Blacknest Research Centre (AWRE, Aldermaston, seismic monitoring)

1975: SATNET starts, direct US-UK link (Post Office & UCL) using Intelisat IV

19767: Terrestrial link UCL – Royal Radar and Signal Establishment (RSRE) opened by Queen. SATNET extended to Norway, Germany and Italy.

1977 EPSS link giving national access through packet-switched service

1979: Major demo using TCP/IP from RSRE via ARPANET (UCL) then SATNET (to Washington) then ARPANET (to SRI in Menlo Park) to Car on Bay Bridge (using Packet Radio). Alternate link to ARPANET established via IPSS international packet-switched service.Norwegian Defense Establishment link by satellite.

How did you contribute to the development of the Internet?

- First of all, not only having ARPANET becometo get international, which was just a question of **Larry Roberts** givingave to me the TIP and link, but developing thisit into a real user community, first of all in Britain. We must If you compare what happened in the UK with what happened in Norway, Italy and Germany, which all had satellite IMPs from ARPANET as well. The, servicesthey didn't developed in any of them, and it didn't developed because in none of those three other countries was, there the effort devoted was a slightest attempt to really bringing in a user population and to track coordinate whatever was happening in nationally with what was happening in the US. It was being much too opportimunistic to think you could bring it in such a minute radically different concept, and import it straight into the European countries.; It was necessaryyou had to follow what was happening in Europe, track it and to adaptmake things compatible to your country – which required political and technical effort and prolonged dedication (on both sides of the Atlantic). What I did technically to connect the heterogeneous networks was And that I think was for a while an exchange novelty and it worked. However, it was not efficient, it

was never going to scale to, where we wanted the internet wanted to scale, but at least it made it possible to get a lot of experience of it. From the beginning and build up so when, they moved ARPANET over from NCP to TCP/IP (in January 1st 1983), we were ablet the decision to move over to the proper internet as it is today.

- The time line above showed that the UCL activity was much broader than just academic. The links to RSRE, Culham, Blacknest and CADC all went well beyond academic links, and brought In the support to maintain the service.
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- I think the other thing that is very important aboutO our contribution alsois that it kept the US side much more internationally minded. I don't know if you are aware, that in 1981 Vint Cerf started two different activities; the international collaboration board (ICB) for the defense and the international activity board (IAB). I ran the ICB from 1983 to about 2003. It was small, it only had some 6 or 8 defense departments (from Canada, the UK, US, Germany, the Netherlands, sometimes Norway, NATO and Denmark); that was small but at least it kept the international presence going on for these things. I killed it when DARPA said the thing could no longer attend if it was outside North America. I felt that it was no longer International enough, so there wa's no point in continuing it. It wa's not so much forof cutting expenses, it was's much more the US become more, that part of the US suddenly became much more introverted.
- Another important point was that it broadened the US international interest. It was the success of our activity that had the US National Science Foundation approach us in 1983 to forge other international links. These I arranged first bilaterally and then with other countries around one of my ICB meeting (see above). Incidentally this also led to discussions amongst the US agencies (NSF, DARPA, Energy and NASA) on joint funding of links. introverted.
- I think the US has always been strong but sometimes it is being more international minded than other times and I think it is not its most international commitment, the moment it would like people to approve its policies, to collaborate with its policies, it would necessarily do other things.

- There are other contributionsthings. W; we were very heavily involved in multimedia for a long time, and I think it was more linking; some of these things were, originally justit was UK-US but later it became very much more European-US as well. S, so, for instance, I ran a whole series of multimedia European projects which had me collaborate with the US for quite a while. And I think inT the project we did weremade, we always did something a little

bit different in attitude. This was ~~but~~ not ~~me~~ in a~~the~~ major way, but we kept international presence for these things.

During the personal interview at the Kelvedon Hatch secret nuclear bunker (UK). October 30th 2006.

I would say ~~developing it,~~ bringing the ARPANET to the UK ~~it~~ was comparatively easy but to develop a user population wa~~i~~s much more difficult. ~~In fact, it must have been; the Norwegian one must have been days before ours. The reason it must, although the original aim was to go by satellite to Goonhilly Downs (UK) and then by leased landline to Norway, by the time it happen (which is two years later), there was both the Tanum (Sweden) station and Goonhilly Downs station and I believed the first one landed in. The IMPs came on the same time, which one was connected first, it was days, and I don't remember which one first. I think initially one was by satellite and I think initially ours must have been first. Initially there was a leased land line of 9.6 Kbits from the UK to Norway.~~

~~The reason for this is that there was something called the nuclear monitoring research organization, DARPA office. That was doing nuclear monitoring of its presence and that had 3 large sites, one in Alaska, one in Montana and one in Norway. And that had a 2.4 Kbps link, (from Norwegian to Washington).~~

~~**Larry Roberts**' initial idea was first of all to put the array to the ARPANET, second was to do analysis and increase the line speed to 64K from 9.6K.~~

That's how the whole thing started as far as I'm concerned. They had the line already except for the fact that they also needed to break the line internationally which wasn't allowed of course, and I had to find out about it. At those days, the idea of an academic asking the post office about a defense line, which was international and we had very strange things in the first few years of that. In July 1973 when the TIP arrived and was installed, the communications line went from Washington D.C. to Goonhilly Downs' (UK) ground satellite base station and from there to London; in London it was less than an exchange and there it went by underwater cable to Norway. I had a feeling that somewhere around 1972 or early 1973, the main line, the one going to Nassau actually went to Tanum and then straight to Nassau so I believe that the line went from Norway to London when the satellite link went to Norway.

That changed, by early 1975 because that's when the SATNET project probably started and then we had satellite IMPs, both in Goonhilly Downs (UK) and in Tanum (SE) and in Germany.

The US did it because it didn't need to invest very much money. It was fairly easy just to put in an extra IMP; that wasn't very difficult, I mean they were deploying already 40 or 50 so putting one more next to one in Norway wasn't very difficult. The contract without... They could see already then, that they are going to need to expand that; I remember being in the office of the Director of Nuclear monitoring research office, caught him talking to one of his friends in France, in the same department and he was complaining "every time I put in a seismic radio, we have very small ones and we have big ones, they going to have a revolution in the place" and they already had quite a few in place, small ones, in Africa and Asia. Fairly early on, in 1974, I had a link straight to the intelligence authority. On the peaceful side, I meet with... which was doing the monitoring of explosions, but that's the peaceful side. I have that for about 20 years.

Who are some key people in the development of Internet, leaders or trendsetters?

First of all, quite clearly **Larry Roberts** for starting things off and then **Bob Kahn** made the key decisions over the next twelve year-, and clearly **Vint Cerf**,- **Jon Postel**, **Steve Crocker** -and Paul Mocapetris played vital roles – probably reflected I other contributions in this book.for really keeping things going throughout in the very conscientious fashion. I think one of those who is under--credited and under--rated is **Dave Mills**; first of all, he was the first person who broke the monopoly of the gateways; he put together his own gateway called the *fuzzball*, where he was very good at that. The impact that was clear since we at one stage there werehad 50

fuzzball nodes (at the NSFnet) all doing different things~~, was itself another whole concept~~.

Technically the most important contributors in the UK to the UCL activities were ~~A person that belongs to government but did a lot of the early work at the UK is~~ **Peter Higginson, Jon Crowcroft and Steve Kille.** Peter was responsible for ~~; he did~~ all our early~~the~~ software until h~~. H~~e left our group in 1976. **Jon** has played a vital part since 1979. He was a key player in our relations with DARPA, and been very influential in Internet developments. ~~I want to mention from the British side:~~ **Steve ~~Kille~~** played a vital role in maintaining the integrity of our gateways throughout the 80s, and ensuring that the UK mail and directory standards were as compatible with the Internet as he possible. ~~(from the mail side); I would say those are really important~~.

Donald Davies, of course, has been key. His contribution has been ~~but he is~~ more from a theoretical point of view, ~~rather~~ than the internet point of view. Davies created the NPL-network but the problem with it~~the NPL-network~~ was that it was an *in house* network only; they were~~as~~ never able to get any funding at all for going outside NPL~~. EPSS[10] was different; The British post office decided that they would put in a packet switched service; initially internationally: EPSS. In order to do that, they would first put in an experimental network and that is what the EPSS was. I was under the strict instruction (and I suspect Davies was as well), that we had to provide access facilities to our networks through this and I did provide EPSS access through our PDP 9. The PDP 9 was running all protocols and nothing else, which is all they were there for. I had three of them and towards the end of the time I need to have an extra one in case one of them broke down~~. ~~And so the EPSS had very little to do with Davies. What~~ Davies was in particular concerned with~~, is something called~~ the **EIN** (the European Informatics Network). He started up that network putting things in from NPL and getting others (particularly France with **Louis Pouzin**'s *Cyclades-network*) and ISPRA (in Italy) among others~~, but that was not with NPL; NPL network was never outside the NPL Laboratory~~.

We also used International packet-~~-~~switched services (from ARPANET), but Donald Davies was never able to do that; he was never able to get out and that was very sad.

Paul V. Mockapetris for creating in 1984 the Domain Name System (or DNS).

[10] ~~EPSS: Enhanced Packet Switching Service. It was an experiment of the UK Post Office. Ferranti supplied the hardware and software. The handling of link control messages (acknowledgements and flow control) was differed from that of most another networks and is not fully explained in the published literature.~~

Another one extremely important but you don't hear much in these days, on the radio side is **Jim Matthis**. Also on the routing side, **Dave Walden** was always very important. ~~**I feel**~~ **Frank Heart** (BBN group leader) did a very good job on the switch (the IMP[11]) part but it was not in very strategic portion of the Internet ~~it~~, H~~I don't think h~~e was not involved in the internet side of the thing at all, as far as I know. The IMP was a packet switch. ~~**I would say that**~~ **Ginny Strazisar** was fundamental to~~,~~ creating the first gateway. Somebody else who again is forgotten about but probably did more to revolutionize things than anybody else is **Leonard Bosack** (Cisco co-founder). Did ~~they never mentioned~~ him to you? And by the way, we had the first Cisco router in Europe here at the UCL – and still have it!~~.~~ Len was showing it in Paris and later dropped it off in UCL~~my place~~. ~~But~~ Len, ~~again,~~ made a successful product of this, ~~when nobody else by the time there~~ was really~~nobody who was~~ competing with PROTEON (then the router leader). We all know Proteon died ~~but later on they died~~ whereas Cisco flourished~~Len survived~~. Of course it did require **John Morgridge** to make Cisco what it is today.

And of course, **Bob Metcalfe**, because again, the Ethernet was absolutely vital and is now everywhere. One who could have had a strong impact but in the end didn't was **Maurice Wilkes**, (Cambridge UK). H~~h~~e didn't because even though he invented ~~came on~~ what ~~it~~ could have been a good access technology, (the token ring) he didn't like to bother with ~~have~~ standardization - so that it never really took off~~, so it wasn't a good access technology anymore~~. One of the really far thinkers~~ing~~ one is clearly **J.C.R. Licklider**; while ~~even I don't think~~ he had little ~~much~~ to do with the internet itself~~, but~~ he was thinking broadly around this.

You can't ~~do anything without~~omit, of course, **Tim Berners-Lee** ~~of course~~, but that's obvious. I think the first person who probably put more order onto the security side than anybody is **Steve Kent**. Steve is really a very intelligent person and he's followed this security issues from the beginning.

Len Kleinrock started a lot on making measurements respectable, but actually the person who has really done most on ~~I really liked from~~ the measurement side is ~~the gal in San Diego,~~ ***Kimberly*** **C. Claffy at US**, she is the one who has done more than anybody else in

[11] IMP: Stands for Interface Message Processor. Created at Bolt Beranek and Newmann in 1969.

measurements lately and she ran a part measurement center at UCSSD - even though she is not an old timer.

A couple of anecdotal situations

- So just to give you a simple example, the DNS came in around 1984. At the same time the British were developing the Network Resource System of UK hosts. TAnd the Americans decided the way how to do was it: to express my address assay kirstein.cs.ucl.ac.uk. The British always know better, so they decided to do it as kirstein@uk.ac.cs.ucl (just the opposite way). So I tried to persuade the British to change, they said "what right has a small research group to change what we do nationally?" so I tried to get ARPA to change "what right have you a small foreign research group to change what we do in the United States?" So I had to update both sets of tables every night to will keep them compatible. so I thenrefore had to look at every message, at everything that came through our gateways, and work out which way around the domain name shouldshould it be. – since oftenSometime people send their address to each other in messages saying it should be the other way around! Our algorithms and that worked very well until 1986 or 87 and then there was a disaster. Czechoslovakia joined the internet!. Czechoslovakia has the country code of .cs and when we got a .cs, I couldn't do it anymore; there was no way you could anymore to guess which way roundte it should be. But among other things that were happening is that the DNS in the US, there was something called the network resource system, these are completely different. So I had to update both sets of tables every night so it will keep compatibility. Now the impact of that was the British could do what they like and still apparently be on the internet and that's what happened. So it's a rather long process. Finally even the Britishthey changed it in the early 1990's.

- I had told you that I had my Ggoverning Ccommittee and they insisted that I put access control and accounting in our network because they were worried that one part of the Research Csuch council would payill get paid too little compared to another part., so I had to do very careful accounting accounting. and because I hadve been given a 48 Kbps free line one way by British Telecom to do some measurements for them; (a 48 Kbpsits transatlantic link per second line was was a lot for 1979/80; it (that was the analog version of tahe 64 Kbits digital line). I also, so I had another48K and 9.6Kbps one way with X.25 and then SATNET, which was 64Kbps. and I could use them both ways. I had access

control and accounting ~~on~~ available, but I didn't particularly bother to turn it ~~about it~~ in the direction from the US to the UK. ~~and~~ I put all the traffic one way so I ~~didn't end up paying anything or~~ paid the minimum and I ~~put access control but I~~ didn't look at the accounts since I did not ~~have~~ hafe to pay. Then the Ggoverning Ccommittee, ~~through the person from the post office~~instructed me to put on ~~said "look, he must have~~ access control both ways. Therefore ~~" so~~ I ~~put access control on principle and I~~ sent out a message to everybody who had~~ve~~ passed through my system in the previous 3 or 6 months, using the e-mail addresses from my accounting system, saying that we had automatic logs already and that in 2 or 3 months time we would apply access control. We would block all traffic from those who had not~~; if you haven't~~ registered and had not been approved to use the link.~~haven't got the right passed with whatever you are doing at the time, then your traffic would be blocked.~~ At this, ~~nd~~ if I may use an expression, *th*e*at* ~~*wind*~~ *shi*~~*ft*~~*ed* *hi*~~*tt*~~*the* *fan*; I suddenly got a storm of hate email the like I have never had before or since, from~~; also it was for~~ about 5.000 people; Many were ~~many others followed~~ from third~~other~~ countries – even though I was strictly forbidden to do ~~...~~ ~~(even~~ international communications at ~~were strictly not allowed that by~~ the time~~)~~. Nobody had realized that the I~~i~~nternet had actually happened, that people were going one way through UNIX email, through BITNET, through any number of different ways and then automatically, because that's the way the DNS works, were coming back through the cheapest, the quickest, or the best route; through my linke. ~~And so~~The e-mails berated me stating ~~they said~~ "what right do you have to block my email?" T~~because t~~hey had no idea they were using my system, it was completely automatic that direction. One suddenly realized that nobody had the slightest idea what ~~the~~ routing topology was in place~~at~~. W~~ that stage; w~~e had no idea ~~-~~ but nor did anybody else; ~~nobody had the slightest idea; W~~~~w~~e knew who were going through only ~~,~~ because we had many weeks of automated logs~~; we just had not had any reason to consult them, we could just look at them, even there was no reason to look at them~~. ~~Remember~~ W~~that w~~e thought that we were running a complete national service ~~at any case; . But this is~~ in fact it was even more than a national service because by that time there were also European direct connections ~~directly~~ and nobody had any idea anymore who was going through what. ~~and they didn't even know they used emails;~~E~~ e~~very~~one~~body ~~thought they were living in a closed world, but they weren't.

- And by the way, ~~that is one place~~ Andreu, ~~w~~here I must take exception with one thing you said in your public speech today. You talked about "switches" and then said, "Which we now call routers". But of course, they are very different. ~~and the point was, W~~~~w~~e now have proper gateways, there can be ~~and that make a~~ a completely different communication system on two ~~other~~ sides of a

gateways. This was what had and that's what happened and , that made a bigcompletely difference even though not all used the Internet Protocols.

The Gateway genesis:

- The reason they were put initially was because although DARPAthere was developing were three different networks: and you're right, packet radio, packet satellite and ARPANET. W, whenever one wanted to makedo any change in any type, and this waiis in 1973/74, the only people that cwould do ithe change (because they were running the old switches) wereas BBN - because they were developing all the switches' code. With e and every change time one want to do it, one waswe were told that there would beis a delay and significantit costs. quite a lot to do it; **Bob Kahn** was very unhappy about that and the original reason that gateway development was were put in place, was in order to have key separation between the network-dependent part and their interconnection. Thus he hoped to part which ends his complete dependence on at **Frank Heart's** group, so release one from the tube at BBN. In practice, But another division of BBN wongot the contract to do gateways, so the monopoly stayed with BBN. However, since but the fact that it was a different group (with **Ginny Strazisar**) doing the gateways it made that make a huge difference and allowed others to workof course then in parallel, **Dave Mills** was developoing a gatewayit too, and this proved one of the most important development that led to the Internet as we know it.

- In the early days Fairly earlier on, I remember at those days international switched communications was completely the monopoly of carriersere simply not allowed. You weren't allowed to have switched telephones attached to two portions of a leased network, or multi-country communicatons. or other types and I remember early on, in 1975, the British RAL Network that I've talked about already includedhad its leased lines to my complex including and CERN in Geneva.our center. I got a request from CERN, could theyywe link to the ARPANET from CERN through usyou? So I had to pass the request to ask my Ggoverning Ccommittee. Of course and my governing committee to the post office man, and of course, they said "no". We then said we do not allow this but please tell us what w e wereyou are doing to prevent this. My The problem was that I was allowing anybody on that centralized research network to use ARPANET, but had to prevent anyone in; it was a centralized research network. I was letting everybody to go out except CERN goingto go through? How did I should stop CERN? What am I going to do to prevent it? So I wrote back: "Tthe following of the five methods they can get through with, I can prevent. The sixth methods that I can't prevent isare the following; ;XYZ. Sshall I put up a notice at CERN, saying you

mustn't do XYZ, ABC because otherwise it would illegally go through to the US"? They decided I shouldn't put up that notice.

- All of these activities took a lot of work, it's not for nothing because we started thinking very early on about access control and security and that was important. We got to be very heavily involved on that later of course.

- "Incidentally, the German, Italian and Norwegians did not pursue a similar route. In the late 1970s, their growth of National Research networks was much slower, and quite divorced from any strong Internet links. Moreover, they had no equivalent of the UK Governing Committee, and never persuaded their Carriers to agree to the liberal interconnection policies adopted by the British Post Office and later British Telecom. For this reason it was not possible for a significant academic involvement from those countries with their US colleagues, until USENET, EARN and other similar Internet developments took off in the middle 1980s". [Excerpt from Ref #2]

What do you think about the future of Internet?

The first think, I am very interested on watching Iinternet's impact on areas it hasn't gone to before, where the impact is huge. I get amused to some sense that history is repeating itself. The problems we had in the 1970's and early 1980's in getting the need to support for research communities things accepted in the UK, and the rest of Norway Europe and Japan then have to be played through again in the late 1980's and 1990's are surfacing again in the rest of Europe and Japan and some other countries. And in 2006 having to be played through yet again in many other countries I deal with. Problems are that we need to support these things, particularly research communities;W we just have just done a short report on the status of funding and services in the newly independent states in Central Asia and the Caucasus and virtually none of them have state funding for their research networks. We are putting in money from NATO and UNDP and a few other people but there is no national funding yet. They still don't realize its importance; the same happens of course in Africa.

When IPv6 does come in properly it will have an immense impact; sooner or later it will do something even about the address shortage going on in several places; that will have a major impact on services you have to use.

Speed,I it is obvious that the need for speed everything is always going up. I see very clearly that the battle to have all real-- time services going over IP has been pretty well won. What impact it is going to have on the whole communication perspective of the companies, is not clear yet. This will be particularly relevant to energy

provision – where the disadvantages of IPv4 and NAT provision are not yet realized by either the suppliers or their regulators.

~~There's more than that,~~T ~~t~~he battle of circuit switch telephone exchanges is over too; circuit switching will disappear in the short – medium term T ~~and for the long term its over but t~~he impact that this will have ~~it has~~ on the finances of the whole communication industry is not ~~over~~ yet evident~~and that should be a very difficult interest in one which to watch.~~ . It is~~But, it all~~ went very well for *Skype*[12] to say that this thing is free but that implie~~d~~s that there's new infrastructure and how that infrastructure is going to be maintained under this, is not clear. The whole question of convergence and how much~~whether or not~~ the mobile and entertainments industry will change is still not clear.

There's a lot of re-arrangement and many things happe~~n~~ning in the telecom industry but it is already all related to the internet.

Do you see any technological trends?

Well, obviously fiber yes, fast switches yes, I think satellite will continue in the parts of the world I deal with; it's quite clear that fiber will take over in principal places and cities but if you look at geography or topography of central Asia, there's no chance that fiber would go through all the places. So the strategy we have is we are putting in satellite now, we expect to be able to put in fiber to the main cities~~apitals~~ within the next 2 or 3 years, and then we'll move the earth stations more to the remote regions of the countries; I think that's what is going to happen. It's a NATO effort, it's my job to do a little bit of deal making so NATO is paying for the main part of communications, and I have persuaded the European C~~c~~ommission to pay for the management of a NATO project, which I think it's the first time it ever happened. I persuaded *Cisco* to donate a local area network in every country, nine countries to go between the earth station and the national research network and then we got a little bit of money from ISOC and a little bit of money from various others. ~~But we are going to get some probably from the Agakhan because of the university in Central Asia, in the mountains,~~ T~~t~~he World Bank is interested in doing video conferencing in some of the remote places, W~~w~~e have put VoIP terminals and a video conferencing system in each of the countries and we are now working ~~with~~ the desktop conferencing. These are, of course, ~~the~~ things that we used to do 20 years earlier in the West.

[12] skype: is a software application that allows users to make voice calls over the Internet. Calls to other users of the service and, in some countries, to free-of-charge numbers, are free, while calls to other landlines and mobile phones can be made for a fee. Skype was written by Estonia-based developers Ahti Heinla, Priit Kasesalu and Jaan Tallinn, who had also developed the file sharing P2P software called Kazaa.

October 30th 2006. Peter Kirstein and the author during the interview at the Kelvedon Hatch secret nuclear bunker.

Lessons learnt

"A key factor in the early start of the project was that a small number of key people could make individual decisions and investments for a speculative project, in a way that was quite impractical for larger committees.

Second was the lucky chance that Government intervention, in the form of the Customs and Excise, forced the project to remain in private hands in the UK; if it had been under a Government Agency, it would surely have been killed at some vital juncture in its first decade.

As an example of the danger, I was requested by one Agency in the late 1970s to stop working on the Internet Protocols and work exclusively on International Standard ones; needless to say, I refused. In private hands, even when the going was rough from one source, another could be mobilized". [Excerpt from Ref #2]

ADDITIONAL READING

PAPERS & BOOKS MENTIONED / RECOMMENDED

[1] Vinton G.Cerf, Peter Kirstein, ***"Issues in packet-network interconnection"*** *Proceedings of the IEEE*, pp. 1386-1408, November 1978.

[2] Peter T. Kirstein, "***Early Experiences with the ARPANET and INTERNET in the UK***", Department of Computer Science, University College London, 1998.

[3] Peter T. Kirstein, ***"The early history of packet switching in the UK"***, IEEE Com-munications Magazine, Vol. 47, no. 2, February 2009 , pp. 18-26